

DESCRIPTION on Amendments under Article 34

Page 4, line 15 : " the same devices " is replaced with -- the devices with the same characteristics --.

5 **Page 14, line 10:** " the same devices " is replaced with -- the devices with the same characteristics --.

Page 15, line 24 to Page 16, line 3: " when a large resistance value is selected, the characteristic of the output range, which shows a proportion that is occupied by the input/output 10 characteristic with a large slope, becomes large. Conversely, when a small resistance value is selected, the characteristic on the output range, which shows a proportion that is occupied by the input/output characteristic with a large slope, becomes small." is replaced with -- as a large resistance value is selected, an output range characteristic is shown in which the input/output 15 characteristic with a large slope occupies a larger proportion, and conversely, as a small resistance value is selected, an output range characteristic is shown in which the input/output characteristic with a large slope occupies a smaller proportion.

20 **Page 16, line 15:** " the same devices " is replaced with -- the devices with the same characteristics --.

Page 18, line 20: " peak amplifier 6 " is replaced with -- peak amplifier 4 --.

25 **Page 18, line 21:** " peak amplifier 6 " is replaced with -- peak amplifier 4 --.

Page 18, line 22: " peak amplifier 6 " is replaced with -- peak amplifier 4 --.

Page 21, line 16: " the same devices " is replaced with -- the devices with the same characteristics --.

Page 22: " Claims 1 and 2 " are deleted.

Pages 22 to 23: "Claim 3" is replaced with "A Doherty amplifier comprising:

- an input terminal;
- input branching means for distributing a signal applied from said input terminal to a first path and a second path;
- 5 a carrier amplifier for amplifying a signal distributed to the first path by said input branching means;
- a peak amplifier for amplifying a signal of a predetermined level or higher among signals distributed to the second path by said input branching
- 10 means;
- output combining means for combining an output of said carrier amplifier with an output of said peak amplifier; and
- a gain compensator disposed at a position ahead of said peak amplifier in the second path for changing a gain in accordance with the level
- 15 of an input signal in order to correct the level of the signal distributed to the second path,
- said carrier amplifier and said peak amplifier being devices having the same characteristics,
- 20 said peak amplifier having a gain smaller than an ideal gain,
- wherein said gain compensator has a larger gain, when a signal equal to or higher than the predetermined level is applied, than a gain when a signal lower than the predetermined level is applied, said gain being set based on a transfer conductance of said peak amplifier.

Page 23: "Claims 4 and 5" are deleted.

25 **Page 23 :** In claims 6 and 7 " according to claim 1" is replaced with -- according to claim 3 --.

Attached is a set of the substitution sheets of the English translation for incorporating the amendments under Article 34 of PCT. The substituting sheets are total 10 sheets including pages 4, 4/1, 14, 14/1, 15, 16, 18, 21, 22 and 23.

Further, Document 5 (Published Japanese Translation of PCT

International Publication for Patent Application No. 2000-513535) has proposed techniques by which a detector directly or indirectly detects the power level of an input signal and the magnitude of the signal, such that bias

5 controllers of a carrier amplifier and a bias amplifier control biases for the carrier amplifier and peak amplifier, respectively, relying on the detected value.

However, whether it be the techniques of Documents 3, 4 or 5, they all requires circuits for making determinations, control and the like, thus

10 leading to a problem that the configuration becomes complicated.

DISCLOSURE OF THE INVENTION

It is an object of the present invention to provide a Doherty amplifier which is capable of accomplishing a linear amplifying and a power combining operation closer to the ideal in a simple configuration, for example, 15 even if the same devices are used as a carrier amplifier and a peak amplifier.

To achieve the above object, a Doherty amplifier according to the present invention has an input terminal, input branching means for distributing the signal applied from the input terminal to a first path and a second path, a carrier amplifier for amplifying the signal distributed to the first 20 path by the input branching means, a peak amplifier for amplifying the signal of a predetermined level or higher among the signals distributed to the second path by the input branching means, output combining means for combining the output of the carrier amplifier with the output of the peak amplifier, and a gain compensator, which is disposed at a position ahead of 25 the peak amplifier in the second path, for changing a gain in accordance with the level of an inputted signal in order to correct the level of the signal

load impedance, which is viewed from carrier amplifier 3, is also in an optimal state in which the maximum output can be transferred to the load, so that the maximum output of the Doherty amplifier can be generated.

Next, a description will be given of an actual operation of the
5 Doherty amplifier.

When the Doherty amplifier is actually designed, devices having substantially the same characteristics are often used for carrier amplifier 3 and peak amplifier 4. This is a configuration called "classical Doherty."

For example, when the saturated power of a Doherty amplifier is
10 set at 100 W, the same devices, the saturated power of which is 50 W, are used as a carrier amplifier and a peak amplifier. Of course, instead of this, a configuration called "extended Doherty" may be used, in which the devices differ in saturated power. However, because the basic principles are the same, description and the like for that case are omitted.

15 However, when a Doherty amplifier is made up by using devices which have the same characteristics as a carrier amplifier and a peak amplifier as described above, ideal characteristics of the Doherty amplifier cannot be accomplished just by simply combining the carrier amplifier with the peak amplifier, having the same characteristics, as illustrated in Fig. 1 as
20 the prior art. For this reason, a lower coefficient, lower saturated power, and degraded linearity will result near the saturated power.

Fig. 6 is a diagram showing an example of the degradation which occurs in an actual Doherty amplifier, showing the input/output characteristics of main parameters similar to the ideal state shown in Fig. 4.

25 As described above, in the ideal state, the current of peak amplifier 4 must reach the maximum value at the maximum point of the input

voltage. Contrary to this, in the example shown in Fig. 6, transfer conductance gm is only one-half of a value required as an ideal value. Thus, even if the input voltage is maximized, the drain current merely reaches one-half of an ideal value.

5 For this reason, an ideal operation of the Doherty amplifier fails. According to a simple calculation, the drain efficiency at the maximum input is 58.9 %, which is about 20 % lower than 78 % that occurs in the ideal state, the output decreases to 50 % of the ideal state, and the input/output linearity degrades to the output level that is 0.5 when the input is 1.

10 Thus, in the present invention, a Doherty amplifier that operates at optimum performance can be implemented by disposing a gain compensator, the gain of which varies in accordance with the magnitude of an input signal, as an example illustrated in Fig. 3a, at a position ahead of peak amplifier 4. For example, even if devices that have the same characteristics are used as 15 carrier amplifier 3 and peak amplifier 4, the resulting product can operate as an ideal Doherty amplifier.

20 In the case of this embodiment, specifically, the characteristics of gain compensator 6 shown in Fig. 3b may be set such that the output signal increases substantially by a factor of two in response to an increase by one of the input signal when signal V_{in} is at 0.5 or more, as shown in Fig. 7.

25 The characteristics as mentioned above can be approximately accomplished by selecting appropriate diodes 61a, 61b and peripheral resistor 62 in the exemplary circuit as illustrated in Fig. 3a. For example, when a large resistance value is selected, the characteristic of the output range, which shows a proportion that is occupied by the input/output characteristic with a large slope, becomes large. Conversely, when a small

resistance value is selected, the characteristic on the output range, which shows a proportion that is occupied by the input/output characteristic with a large slope, becomes small.

Consequently, when this gain compensator 6 is disposed at a 5 position ahead of peak amplifier 4, and when the input level to gain compensator 6 and an operating state are set such that the output range start point of gain compensator 6 is positioned near the threshold voltage ($V_{in}=0.5$) of peak amplifier 4 or at the threshold voltage ($V_{in}=0.5$) of peak amplifier 4, the gm characteristic of peak amplifier 4 can be apparently 10 doubled, making use of a region in which the slope of the input/output characteristic is approximately two.

Stated another way, peak amplifier 4 has a maximum drain current at the time that the input level reaches the maximum value. Therefore, it is possible to accomplish an ideal state of the Doherty amplifier 15 from the transition point to the saturated state. As such, even if the same devices, for example, are used for the carrier amplifier and peak amplifier, it is possible to implement a Doherty amplifier that can present a linear amplifying and a power combining operation closer to the ideal in a simple configuration.

20 Describing in greater detail, in the case of this example, the input level to or the operating state of gain compensator 6 is set such that the gain of gain compensator 6, i.e., the slope of the input/output characteristic of gain compensator 6 is one or substantially one when the level of a signal applied to input terminal 1 is equal to or lower than the threshold voltage of 25 peak amplifier 4, and the gain of gain compensator 6, i.e., the slope of the input/output characteristic of gain compensator 6 is two or substantially two

higher than the predetermined level. It is therefore possible to perform a linear amplifying and a power combining operation closer to the ideal in a simple configuration as described above.

Also, because the gain of gain compensator 6, when a signal that

5 is lower than the predetermined level is applied from input terminal 1, is set different from the gain of gain compensator 6 when a signal that is equal to or higher than the predetermined level is applied, the linear amplifying and power combining operations closer to the ideal can be performed in a simple configuration, as described above, without changing the amplifying operation

10 start point of peak amplifier 4 (the threshold voltage of peak amplifier 4) for the signal applied from input terminal 1.

Also, when the gain of gain compensator 6, when a signal equal to or higher than the predetermined level, is larger than the gain of gain compensator 6 when a signal lower than the predetermined level is applied,

15 the gain of the peak amplifier, when the peak amplifier performs an amplifying operation, can be increased to an ideal gain without changing the amplifying operation start point of the peak amplifier for the signal applied from the input terminal, if the gain of peak amplifier 4 is below the ideal value.

As well, the gain of gain compensator 6 is set based on the

20 operation characteristic of peak amplifier 6. Thus, in addition to the aforementioned effects, the gain of peak amplifier 6 and/or the amplifying operation start point of peak amplifier 6 (the threshold voltage in this example) can be compensated for with high accuracy.

In the foregoing, an example has been shown for the case where

25 transfer conductance gm of peak amplifier 4 is just one-half as much as a value that would be required as an ideal value, and an example has been

operating current value in which the desired saturated output power can be generated, for example, the gm characteristic, may be corrected by the gain compensator using a desired value.

Therefore, even when devices, which have different
5 characteristics from each other, are used as carrier amplifier 3 and peak
amplifier 4, it is possible to implement a Doherty amplifier which provides a
linear amplifying and a power combining operation close to the ideal in a
simple configuration.

In the present invention, the gain compensator, whose gain varies
10 in accordance with the level of an input signal, is disposed at a position
ahead of the peak amplifier of the Doherty amplifier. It is therefore possible
to perform an ideal amplifying operation at optimum performance without
requiring a complicated circuit configuration and control for performing
detection, determination, control and the like, as is the case with the prior art.
15 Consequently, it is possible to simplify the configuration and reduce the cost
even when the same devices, for example, are used as the carrier amplifier
and peak amplifier.

In the embodiment described above, the illustrated configurations
are mere examples, and the present invention is not limited to the
20 configurations.

CLAIMS

1. A Doherty amplifier comprising:

an input terminal;

5 input branching means for distributing a signal that is applied from said input terminal to a first path and a second path;

a carrier amplifier for amplifying a signal that is distributed to the first path by said input branching means;

a peak amplifier for amplifying a signal of a predetermined level or 10 higher among signals that are distributed to the second path by said input branching means;

output combining means for combining an output of said carrier amplifier with an output of said peak amplifier; and

15 a gain compensator, which is disposed at a position ahead of said peak amplifier in the second path, for changing a gain in accordance with the level of an input signal in order to correct the signal that is distributed to the second path for the level.

2. The Doherty amplifier according to claim 1, wherein said gain

20 compensator has a gain, when a signal lower than the predetermined level is applied, that is different from a gain when a signal equal to or higher than the predetermined level is applied.

3. The Doherty amplifier according to claim 2, wherein said gain

25 compensator has a larger gain, when the signal equal to or higher than the predetermined level is applied, than the gain when the signal lower than the

predetermined level is applied.

4. The Doherty amplifier according to claim 2, wherein said gain compensator has a smaller gain, when the signal equal to or higher than the predetermined level is applied, than the gain when the signal lower than the predetermined level is applied.
5. The Doherty amplifier according to claim 1, wherein the gain of said gain compensator is set based on the operation characteristic of said peak amplifier.
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6. The Doherty amplifier according to claim 1, wherein said gain compensator comprises a parallel circuit composed of an anti-parallel diode and a resistor, or a parallel circuit composed of a diode and a resistor, or an FET, or a bipolar transistor.
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7. The Doherty amplifier according to claim 1, wherein said carrier amplifier and said peak amplifier are each composed of an FET, and said gain compensator compensates said peak amplifier for a gm characteristic.